

Comment on “Charged impurity scattering limited low temperature resistivity of low density silicon inversion layers” (Das Sarma and Hwang, cond-mat/9812216)

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In a recent preprint, Das Sarma and Hwang [1] propose an explanation for the sharp decrease in the $B = 0$ resistivity at low temperatures which has been attributed to a transition to an unexpected conducting phase in dilute high-mobility two-dimensional systems (see Refs.[1-4] in [1]). The anomalous transport observed in these experiments is ascribed in Ref. [1] to temperature-dependent screening and energy averaging of the scattering time. The model yields curves that are qualitatively similar to those observed experimentally: the resistivity has a maximum at a temperature $\sim E_F/k_B$ and decreases at lower temperatures by a factor of 3 to 10. The anomalous response to a magnetic field (*e.g.*, the increase in low-temperature resistivity by orders of magnitude [2]), is not considered in Ref. [1].

Two main assumptions are made in the proposed model [1]: (1) the transport behavior is dominated by charged impurity scattering centers with a density N_i , and (2) the metal-insulator transition, which occurs when the electron density (n_s) equals a critical density (n_c), is due to the freeze-out of n_c carriers so that the net free carrier density is given by $n \equiv n_s - n_c$ at $T = 0$. The authors do not specify a mechanism for this carrier freeze-out and simply accept it as an experimental fact. Although not included in their calculation, Das Sarma and Hwang also note that their model can be extended to include a thermally activated contribution to the density of “free” electrons.

In this Comment, we examine whether the available experimental data support the model of Das Sarma and Hwang.

(i) Comparison with the experimental data (see Fig. 1 of Ref. [1]) is made for an assumed density of charged impurities of $3.5 \times 10^9 \text{ cm}^{-2}$, a value that is too small. In an earlier publication, Klapwijk and Das Sarma [3] explicitly stated that the number of ionized impurities is “ $3 \times 10^{10} \text{ cm}^{-2}$ for high-mobility MOSFET’s used for the 2D MIT experiments. There is very little room to vary this number by a factor of two”. Without reference to this earlier statement, the authors now use a value for N_i that is one order of magnitude smaller [4].

(ii) According to the proposed model, the number of “free” carriers at zero temperature is zero at the “critical” carrier density ($n_s = n_c$) and it is very small ($n = n_s - n_c \ll n_c$) near the transition. In this range, the transport must be dominated by thermally activated

carriers, which decrease exponentially in number as the temperature is reduced. It is known from experiment that at low temperatures the resistance is independent of temperature [6,7] at n_c (the separatrix between the two phases) and depends weakly on temperature for nearby electron densities. In order to give rise to a finite conductivity $\sim e^2/h$ at the separatrix, an exponentially small number of carriers must have an exponentially large mobility, a circumstance that is rather improbable.

(iii) Recent measurements of the Hall coefficient and Shubnikov-de Haas oscillations yield electron densities that are independent of temperature and equal to n_s rather than a density $n = n_s - n_c$ of “free” electrons [7,8]. This implies that *all* the electrons contribute to the Hall conductance, including those that are frozen-out or localized. Although this is known to occur in quantum systems such as Hall insulators, it is not clear why it can hold within the simple classical model proposed by Das Sarma and Hwang.

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